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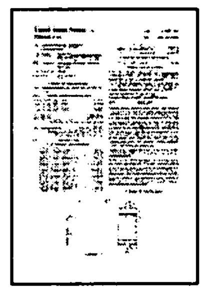
Title:	**US4425143: Adsorption by zeolitic composition**
Inventor(s):	**Nishizawa; Junichi**, Sendai, Japan **Suzuki; Rensaku**, Sendai, Japan **Aizawa; Kenji**, Sendai, Japan
Applicant/Assignee Inquire Regarding Licensing:	**Shin Tohoku Chemical Industries Inc.**, Japan other patents from SHIN TOHOKU CHEMICAL INDUSTRIES INC. (approx. 1) News, Profiles, Stocks and More about this company
Issued/Filed Dates:	**Jan. 10, 1984** / Aug. 24, 1981
Application Number:	**US1981000295387**
IPC Class:	**B01D 53/04;**
Class:	**Current: 095/126;** 095/138; 096/146; 422/169; 423/219; 423/351; **Original: 055/031;** 055/033; 055/075; 055/208; 055/389; 422/169; 423/219; 423/351;
Field of Search:	**055/68,75,208,387,389,31,33 209/567,576,577,580,581,589 252/455 Z 423/219,351 422/169**
Priority Number(s):	Dec. 29, 1978 **JP1978000162338** Dec. 29, 1978 **JP1978000162339** Dec. 29, 1978 **JP1978000162340** Jan. 10, 1979 **JP1979000002032**
Legal Status:	Show legal status actions
Abstract:	Natural zeolite minerals which have a



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         (c) 2001 Engineering Info. Inc.
*File   8: Ei Thesaurus now available through www.ei.org
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         (c) 2001 Contains copyrighted material
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For access restrictions, see HELP RESTRICT.
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               5  AU=DWAIRI IM
               4  AU=DWAIRI, I.
              12  AU=DWAIRI, I. M.
               3  AU=DWAIRI, I.M.
               2  AU=DWAIRI, IBRAHIM M.
               1  AU=DWAIRI, IBRAHIM MOH'D ALI
      S1      27  E3-E8
?s s1 and zeolite?
              27  S1
          146263  ZEOLITE?
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>>>Sort tag 'PY' is undefined for file(s): 319, 77
>>>Records from file(s) listed above will appear at the end of the sorted
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 4/5/1     (Item 1 from file: 34)
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DIALOG(R)File 34:SciSearch(R) Cited Ref Sci

06684746 Genuine Article#: ZK390 Number of References: 20
Title: Evaluation of Jordanian zeolite tuff as a controlled slow-release fertilizer for NH4+
Author(s): Dwairi IM (REPRINT)
Corporate Source: YARMOUK UNIV,DEPT EARTH & ENVIRONM SCI/IRBID//JORDAN/ (REPRINT)
Journal: ENVIRONMENTAL GEOLOGY, 1998, V34, N1 (APR), P1-4
ISSN: 0177-5146 Publication date: 19980400
Publisher: SPRINGER VERLAG, 175 FIFTH AVE, NEW YORK, NY 10010
Language: English Document Type: ARTICLE
Geographic Location: JORDAN
Subfile: CC AGRI--Current Contents, Agriculture, Biology & Environmental Sciences
Journal Subject Category: WATER RESOURCES; ENVIRONMENTAL SCIENCES; GEOSCIENCES, INTERDISCIPLINARY
Abstract: The exchange and release properties of the natural phillipsite tuff from the Aritain area in Jordan were evaluated by studying the exchange properties of this natural zeolite in the NH4+-NA(+) system. Exchange isotherms at 18, 35, and 50 degrees C showed that phillipsite exchanged NH4+ preferably over Na+ at all temperatures. However, the selectivity coefficient for NH4+ decreased with decreasing temperature. The release of NH4+ from phillipsite saturated with ammonium sulfate took place in two stages characterized by different SO42-:NH4+ ratios. Aritain phillipsite from NE Jordan could be processed and used as NH4+ slow-release fertilizers. The use of NH4+-phillipsite tuff offers an option to the widely used soluble NH4-fertilizers in agciculture to avoid environmental problems associated with nitrogen contamination of surface water and groundwater.
Descriptors--Author Keywords: zeolite ; NH4+-phillipsite tuff ; exchange properties ; slow release ; soluble ; NH4-fertilizers
Identifiers--KeyWord Plus(R): PHOSPHATE ROCK; PHILLIPSITE
Cited References:
ALLEN ER, 1993, P31, ZEOLITE 93
BARBARICK KA, 1990, V54, P911, SOIL SCI SOC AM J
BARRER RM, 1971, P2904, J CHEM SOC A
CHESWORTH W, 1987, V2, P291, APPL CLAY SCI
DEGENNARO M, 1979, V30, P329, IND MINERARIA
DWAIRI IM, 1991, V1, P53, ALBALAGA
DWAIRI IM, 1992, V19, P23, DIRASAT
DWAIRI IM, 1992, V19, P7, DIRASAT B
DWAIRI IM, 1987, THESIS HULL U HULL
FLANIGEN EM, 1977, V4, P19, REV MINERAL
HERANDEZ JEG, 1993, V41, P521, CLAYS CLAY MINER
HERNANDEZ JEG, 1993, V37, P1, AGROCHIMICA
HERNANDEZ JEG, 1992, V7, P323, APPL CLAY SCI
HERNANDEZ JEG, 1994, V9, P129, APPL CLAY SCI
HERNANDEZ JEG, 1992, V76, P219, ENVIRON POLLUT
LAI TM, 1986, V6, P129, ZEOLITES
LEWIS MD, 1984, P105, ZEOAGRICULTURE USE N
MERCER BW, 1978, P451, NATURAL ZEOLITES OCC
PIRELA HJ, 1984, P113, ZEOAGRICULTURE USE N
SHIBUE Y, 1981, V29, P397, CLAYS CLAY MINER

4/5/2 (Item 2 from file: 34)
DIALOG(R)File 34:SciSearch(R) Cited Ref Sci

06395984   Genuine Article#: YP621   Number of References: 16
Title: Conserving toxic ammoniacal nitrogen in manure using natural zeolite tuff: A comparative study
Author(s): Dwairi IM (REPRINT)
Corporate Source: YARMOUK UNIV,DEPT EARTH & ENVIRONM SCI/IRBID//JORDAN/ (REPRINT)
Journal: BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY, 1998, V60, N1 (JAN), P126-133
ISSN: 0007-4861   Publication date: 19980100
Publisher: SPRINGER VERLAG, 175 FIFTH AVE, NEW YORK, NY 10010
Language: English   Document Type: ARTICLE
Geographic Location: JORDAN
Subfile: CC LIFE--Current Contents, Life Sciences; CC AGRI--Current Contents, Agriculture, Biology & Environmental Sciences
Journal Subject Category: ENVIRONMENTAL SCIENCES; TOXICOLOGY
Cited References:

*AM PUBL HLTH ASS, 1971, STAND METH EX WAT WA
*AM SOC AGR ENG, 1982, AGR ENG YB
ANDREWS RD, 1993, P250, 4 INT C OCC PROP UT
BOULDIN DR, 1981, 81 CORN U DEP AGR
DWAIRI IM, 1992, V19, P7, DIRASAT U JORDAN B
DWAIRI IM, 1997, IN PRESS ENV GEOLOGY
DWAIRI IM, 1993, V8, P7, MUTAH J RES STUDIES
DWIARI IM, 1987, THESIS U HULL ENGLAN
FEBLES JA, 1991, ZEOLITES 91
MERCER BW, 1978, P451, NATURAL ZEOLITES OCC
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VANDYNE DL, 1978, ESCS12 USDA

4/5/3   (Item 3 from file: 8)
DIALOG(R)File   8:Ei Compendex(R)

05022348   E.I. No: EIP98054214834
Title: Evaluation of Jordanian zeolite tuff as a controlled slow-release fertilizer for NH//4** plus
Author: Dwairi, I.M.
Corporate Source: Yarmouk Univ, Irbid, Jordan
Source: Environmental Geology v 34 n 1 Apr 1998. p 1-4
Publication Year: 1998
CODEN: ENGOE9   ISSN: 0943-0105
Language: English
Document Type: JA; (Journal Article)   Treatment: X; (Experimental)
Journal Announcement: 9807W4

Abstract: The exchange and release properties of the natural phillipsite tuff from the Aritain area in Jordan were evaluated by studying the exchange properties of this natural zeolite in the NH//4** plus -Na** plus system. Exchange isotherms at 18, 35, and 50 degree C showed that phillipsite exchanged NH//4** plus preferably over Na** plus at all temperatures. However, the selectivity coefficient for NH//4** plus decreased with decreasing temperature. The release of NH//4** plus from phillipsite saturated with ammonium sulfate took place in two stages characterized by different SO//4**2** minus :NH//4** plus ratios. Aritain phillipsite from NE Jordan could be processed and used as NH//4** plus slow-release fertilizers. The use of NH//4** plus -phillipsite tuff offers

an option to the widely used soluble NH//4-fertilizers in agriculture to avoid environmental problems associated with nitrogen contamination of surface water and groundwater. (Author abstract) 20 Refs.

Descriptors: Geochemistry; Volcanic rocks; Zeolites ; Isotherms; Saturation (materials composition); Composition effects; Nitrogen fertilizers; Solubility; Ion exchange; Thermal effects

Identifiers: Ammonium phillipsite tuff; Ammonium fertilizers; Exchange isotherms

Classification Codes:

481.2 (Geochemistry); 482.2 (Minerals); 804.2 (Inorganic Components); 801.4 (Physical Chemistry)

481 (Geology & Geophysics); 482 (Mineralogy & Petrology); 804 (Chemical Products); 801 (Chemical Analysis & Physical Chemistry)

48 (ENGINEERING GEOLOGY); 80 (CHEMICAL ENGINEERING)

4/5/4 (Item 4 from file: 399)

DIALOG(R)File 399:CA SEARCH(R)

129067287 CA: 129(6)67287z JOURNAL

Renewable, controlled and environmentally safe phosphorus release in soils from mixtures of NH4+-phillipsite tuff and phosphate rocks

AUTHOR(S): Dwairi, I. M.

LOCATION: Dep. Earth Environmental Sciences, Yarmouk Univ., Irbid, Jordan ,

JOURNAL: Environ. Geol. (Berlin) DATE: 1998 VOLUME: 34 NUMBER: 4

PAGES: 293-296 CODEN: ENGOE9 ISSN: 1073-9106 LANGUAGE: English

PUBLISHER: Springer-Verlag

SECTION:

CA219003 Fertilizers, Soils, and Plant Nutrition

IDENTIFIERS: phosphorus ammonium phillipsite fertilizer soil, calcium phosphate fertilizer phosphorus ammonium phillipsite

DESCRIPTORS:

Zeolite group minerals...

Ca2+ satd.; P release in soils from mixts. of NH4+-phillipsite tuff and phosphate rocks

Fertilizer experiment... Phosphate rock...

P release in soils from mixts. of NH4+-phillipsite tuff and phosphate rocks

CAS REGISTRY NUMBERS:

14798-03-9 biological studies, combined with phillipsite; P release in soils from mixts. of NH4+-phillipsite tuff and phosphate rocks

7440-23-5 biological studies, P and Na release in soils from mixts. of NH4+-phillipsite tuff and phosphate rocks

7723-14-0 biological studies, P release in soils from mixts. of NH4+-phillipsite tuff and phosphate rocks

12174-18-4 NH4+ contg.; P release in soils from mixts. of NH4+-phillipsite tuff and phosphate rocks

7757-93-9 P release in soils from mixts. of NH4+-phillipsite tuff and monocalcium phosphate

4/5/5 (Item 5 from file: 8)

DIALOG(R)File 8:Ei Compendex(R)

04523164 E.I. No: EIP96103362007

Title: Removal of nutrients from sewage effluent in stabilization ponds using natural zeolite

Author: Gharaibeh, S.H.; Dwairi, I.M.
Corporate Source: Yarmouk Univ, Irbid, Jordan
Source: Chemische Technik (Leipzig) v 48 n 4 Aug 1996. p 215-218
Publication Year: 1996
CODEN: CHTEAA ISSN: 0045-6519
Language: English
Document Type: JA; (Journal Article) Treatment: X; (Experimental); A; (Applications)
Journal Announcement: 9612W2
Abstract: Jordanian natural zeolitic tuff samples were tested as a tertiary treatment on the effluent of wastewater stabilization ponds using laboratory scale column methods. The results of the column method showed that the zeolitic tuff had high efficiencies for ammonium and phosphate removal, and low efficiencies for nitrate elimination. The highest removal value for ammonium was 78.6% using raw zeolitic tuff of 0.5 - 0.25 mm size fraction, while the highest removal for phosphate was 30.05% using Ca-form zeolitic tuff of 0.5 - 0.25 mm grain size. (Author abstract) 11 Refs.
Descriptors: Sewage lagoons; Zeolites ; Effluents; Wastewater treatment; Ammonium compounds; Phosphates; Nitrates; Particle size analysis; Effluents
Identifiers: Natural zeolitic tuff; Stabilization ponds; Column methods; Ammonium removal; Phosphate removal; Nitrate elimination; Grain size
Classification Codes:
452.2 (Sewage Treatment); 452.3 (Industrial Wastes); 804.2 (Inorganic Components); 452.4 (Industrial Wastes Treatment); 943.3 (Special Purpose Instruments)
452 (Sewage & Industrial Wastes Treatment); 804 (Chemical Products); 943 (Mechanical & Miscellaneous Measuring Instruments)
45 (POLLUTION & SANITARY ENGINEERING); 80 (CHEMICAL ENGINEERING); 94 (INSTRUMENTS & MEASUREMENT)

4/5/6 (Item 6 from file: 399)
DIALOG(R)File 399:CA SEARCH(R)

120034882 CA: 120(4)34882a JOURNAL
Jordanian zeolites: evaluation for possible industrial application of natural Aritain phillipsite tuffs
done
AUTHOR(S): Dwairi, I. M.
LOCATION: Yarmouk Univ., Jordan,
JOURNAL: Dirasat - Univ. Jordan, Ser. B DATE: 1992 VOLUME: 19B
NUMBER: 1 PAGES: 23-44 CODEN: DJSSE8 LANGUAGE: English
SECTION:
CA253005 Mineralogical and Geological Chemistry
IDENTIFIERS: zeolitic tuff industrial use assessment Jordan, phillipsite rich tuff possible use Jordan
DESCRIPTORS:
Zeolite-group minerals...
in tuffs, of Jordan
Tuff,zeolitic...
phillipsite-rich, possible industrial application of, of Aritain, Jordan
CAS REGISTRY NUMBERS:
12174-18-4 in tuffs, of Jordan

4/5/7 (Item 7 from file: 399)
DIALOG(R)File 399:CA SEARCH(R)

112162348 CA: 112(18)162348c DISSERTATION
A chemical study of the palagonitic tuffs of the Aritain area of Jordan, with special reference to nature, origin, and industrial potential of the associated zeolite deposits
AUTHOR(S): Dwairi, Ibrahim Moh'd Ali
LOCATION: Univ. Hull, Hull, UK,
DATE: 1987 PAGES: 558 pp. CODEN: DABBBA LANGUAGE: English CITATION: Diss. Abstr. Int. B 1989, 50(6), 2319 AVAIL: Univ. Microfilms Int., Order No. BRDX86284
SECTION:
CA253003 Mineralogical and Geological Chemistry
IDENTIFIERS: palagonite tuff Aritain Jordan, zeolite deposit palagonite tuff Jordan
DESCRIPTORS:
Zeolites,occurrence...
deposits of, industrial potential of, in palagonitic tuffs, of Aritain, Jordan
Tuff,palagonitic...
geochem. and zeolite deposits of, of Aritain, Jordan

Basic Search Advanced Search Search Preferences

(phillipsite) AND (palagonite) AND soil [Search]

☑ All journal sources ☑ All Web sources ☐ Exact phrase

Searched for:	All of the words (**phillipsite**) AND (**palagonite**) AND **soil**
Found:	**17 total | journal results | 17 Web results**
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1. No Title
Aug 2002
...Oxide Feldspar Glauconite Opaques Organic Calcite **Palagonite** **Phillipsite** Pyrite Quartz Volcanic Glass Bryozoa Coccolith Foraminifers...3 72.5 45.81 D 25 15 60 32 2 11 16 1 16 5 16 * Red **soil** 6 R 3 73.5 45.82 M 30 50 15 13 13 9 37 28 Red **soil**...
more hits from
[http://www-odp.tamu.edu/publications/197_IR/VOLUME/TAB...]
similar results

2. zeolites2
Oct 2002
...except for the names harmotome, pollucite and wairakite in the **phillipsite** and analcime series. Differences in space-group symmetry...heulandite-Ca, -Na, -K, -Sr; levyne-Ca, -Na; paulingite-K, -Ca; **phillipsite**-Na, -Ca, -K; stilbite-Ca, -Na. Key references, type locality...
[http://www.minsocam.org/msa/AmMin/Special_Features/zeo...]
similar results

3. DOE/ORP-2000-24, Rev. 0
Aug 2001
DOE/ORP-2000-24 Rev. 0 Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version F.M. Mann, R.J. Puigh II, S.H. Finfrock, E.J. Freeman, Jr., R. Khaleel, D.H. Bacon, M.P. Bergeron, B.P. McGrail, and S.K. Wurstner Ken Burgard, CHG Project...
[http://www.bhi-erc.com/projects/vadose/field/ilaw/ORP_...]
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Oct 2000
...interaction is the pseudo-mineral **palagonite**, which bears strikingly similarities to martian **soil**. Rapid melting of ice by...elevated temperatures produces **palagonite**, a poorly-crystalline...and depletion. The surface **soil** of martian bright regions...
[http://wwwflag.wr.usgs.gov/USGSFlag/Land/IcelandMeetin...]
similar results

☑ **5.** Microsoft Word - Chapter 1. Introduction.doc
Aug 2000
...the formation sequence of Jordanian **Phillipsite**, in the area of discovery, is explained...glass and pore alkaline water leads to **palagonite** with a thin film of inter granular **phillipsite**. b- **Palagonite** react with Mg-rich pore solutions...
[http://docserver.bis.uni-oldenburg.de/publikationen/di...]
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☐ **6.** Ingrid's Rockin' Dictionary
Mar 2003
...detailed notes in W. Clearwater Zeolites f] agglutinate aggregates of lunar **soil** cemented together by vesicular, flow-banded impact glass; usually < 1 mm in size...
[http://www.lpl.arizona.edu/~ingrid/dictionary.html]
similar results

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Dec 2002
...ORDOVICIAN NT: PERMIAN NT: SILURIAN RT: PHANEROZOIC **PALAGONITE** BT: VOLCANIC ROCKS RT: BASALT-SEAWATER INTERACTION RT...PENETRATION DEPTH RT: PENETROMETERS RT: SEDIMENT PROPERTIES RT: **SOIL** MECHANICS PENETROMETERS BT: MEASURING DEVICES RT: CORERS...
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☐ **8.** ASFA Thesaurus
Dec 2000
...Thawing of frozen fishery products. For melting of ice/snow on land and in frozen **soil**, use ICE MELTING. For preventing and removing rime and glaze from decks, superstructures...
[http://www.pmel.noaa.gov/sebscc/special_issue/csa_thes...]
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☐ **9.** 3060.PDF
May 2000
...saponite [3]. Minor alteration components include the zeolites **phillipsite** and possibly gismondine [1]. This suite of minerals is indicative...contains considerably more x-ray amorphous colloidal material (**palagonite**) than clay. The surface ash is extremely dry, while the palagonitic...
[http://cass.jsc.nasa.gov/meetings/earlymars/pdf/3060.p...]
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☐ **10.** GES 300 Sedimentology: Weathering, Soils and Paleoclimates
Jan 2002
...frost wedging in cracks bb. frost heaving below **soil** or loose rock cc. most important ii. fire aa...alteration of volcanic ash aa. vol glass to **palag nite** bb. ash to zeolite (**phillipsite**) or bentonite c. effects: i. widespread leaching...
[http://facstaff.buffalostate.edu/wadellc/sedimentology...]
similar results

Searched for:	All of the words (**phillipsite**) AND (**palagonite**) AND **soil**
Found:	**17 total | journal results | 17 Web results**
Sort by:	**relevance | date**

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Refine your search using these keywords found in the results:
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Or refine using:
All of the words
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11. AAS
Jan 2000
AAS USE: Absorption spectroscopy Abalone fisheries USE: Gastropod fisheries Abdomen UF: Peritoneum BT: Body regions RT: Digestive system Abiotic diseases USE: Environmental diseases Abiotic factors SN: Before 1982 search ENVIRONMENTAL FACTORS UF: Density...
[http://ioc.unesco.org/oceanteacher/information/Course1...]
similar results

12. DOWNLOADABLE VERSION: SESS59.PDF
Oct 2002
Thursday, March 15, 2001 POSTER SESSION II 7:00Â-9:30 p.m. UHCL Mars Surface Properties I Fonti S. Blanco A. Blecka M. I. De Carlo F. Orofino V. Polimeno N. Spectral Emissivity as a Tool for the Interpretation of Martian Data: A Laboratory Approach
[ftp://www.lpi.usra.edu/pub/outgoing/lpsc2001/sess59.pd...]
similar results

13. LEG 197 CORE DESCRIPTIONS, SITE 1205
Jul 2002
...2) CALCAREOUS SILTSTONE with abundant **phillipsite** and opaque minerals (probably hematite...is a layered (sub-cm to cm structures) **soil** horizon. The reddish clay is also finely...minerals, Fe oxides, volcanic glass (mostly **palagonite**) at various stages of alteration. The...
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similar results

14. 5. SITE 1205
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...interrupted by sudden spurts of rapid penetration through thin **s il** horizons be- tween lava flows. Until a depth of 59 mbsf was...Organic calcite (modal%) Feldspar (modal%) Volcanic ash (modal%) **Phillipsite** (modal%) 0 20 40 60 80 100 120 Depth (mbsf) Fe oxide (modal...
[http://www-odp.tamu.edu/publications/197_IR/VOLUME/CHA...]
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☐ **15.** No Title
Nov 2001
H Haak, A.B., and Schlager, W., 1989. Compositional variations in calciturbidites due to sea-level fluctua- tions, Late Quaternary, Bahamas. Geol. Rundsch., 78:477Â-486. Haake, F.W., 1980. Bentische Foraminiferen in OberflÃ¤chen-Sedimenten und Kernen des...
[http://www-odp.tamu.edu/publications/bib/bib-h.pdf]
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☐ **16.** LEG 197 CORE DESCRIPTIONS, SITE 1206
Jul 2002
Core Photo C ORE D ESCRIPTIONS V ISUAL C ORE D ESCRIPTIONS , S ITE 1206 1 cm Piece Number Orientation Lithologic Unit Groundmass/ Grain Size Degree of Alteration Veins Vesicle Structure Vesicularity Phenocrysts (%) Shipboard Studies Graphic Representation...
[http://www-odp.tamu.edu/publications/197_IR/VOLUME/COR...]
similar results

☐ **17.** No Title
Nov 2001
SH-SZ (excluding ODP Proceedings entries beginning with Shipboard Scientific Party) Shabtaie, S., and Bentley, C.R., 1987. West Antarctic ice streams draining into the Ross Ice Shelf: configu- ration and mass balance. J. Geophys. Res., 92:1311Â-1336...
[http://www-odp.tamu.edu/publications/bib/bib-sh.pdf]
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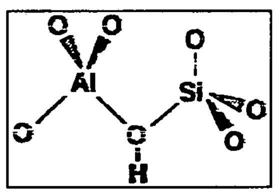
8/2000

Chapter 1. Natural Zeolite: Introduction and Properties.

1.1 Introduction

Natural zeolite minerals are secondary minerals and can be defined as crystalline, hydrated alumino-silicates of alkali and alkaline-earth cations that consist of infinite or finite three dimensional crystal structures of (Si, Al)O_4 tetrahedra, which are linked together by the sharing of oxygen atoms (Mumpton, 1983, Flanigen 1983 and Gottardi, 1978), (Figure 1.1). Their structure contains channels and pores filled with a certain amount of water and exchangeable cations. This water can evaporate when heated to about 250°C (dehydration) and is regained at room temperature (re-hydration) (Gottardi, 1985), also some of cations constituent may be exchangeable from the zeolite inner cavities and pores without any major change of zeolite structure (Mumpton, 1983).

Figure. 1.1 Primary building unit of SiO_4 and AlO_4. Tetrahedra



Zeolite minerals were first discovered in Sweden by Cronstedt in 1756, (Gottardi,1978), who gave them their name, which comes from the Greek word meaning the "boiling stones". Since that time, about 50 zeolite natural species have been accounted for, and in the late 1940's, work carried out on developing a synthesis zeolite under hydro-thermal conditions (temperature < 100°C and at normal atmospheric pressure), more than 100 species have been synthesised in the laboratory, which have no natural counterparts (Mumpton, 1978).

1.2 Zeolite Structures

Zeolite structure contains two types of building units namely, primary and secondary . A primary building unit (PBU) is the simpler and is illustrated in figure 1.1, a tetrahedron of (TO_4) of 4 oxygen ions surrounding a central ion of either Si^{4+} or Al^{3+}. These PBU are linked together to form a three-dimensional framework and nearly all oxygen ions are shared by two tetrahedra (Flangin, 1983; Gottardi,1985). This arrangement reduces the oxygen: silicon ratio to 2:1, and if tetrahedra were centred by Si the chemical formula of its framework would be

Si_nO_{2n}, and the structure would be electrically neutral like Quartz (SiO_2). However , in zeolite structure some of the quadrivalent Si is replaced by trivalent; thus $(Al_mSi_{n-m}O_{2n})^{m-}$, giving rise to a deficiency of positive charge in the zeolite frameworks, and this is balanced by mono- and divalent cations, such as Na^+, K^+, Ca^{2+} and Mg^{2+}, located outside the tetrahedra; in the channels and pores (Mumpton, 1983, Gottardi, 1985; 1978).

The general formula for natural zeolite according to Gottardi can be given as:

$M_xD_y\ [Al_{(x+2y)}Si_{n-(x+2y)}O_{2n}].mH_2O$.

where: $Al_{(x+2y)}Si_{n-(x+2y)}O_{2n}$ represent the framework atom

M: Na^+, K^+, or other monovalent cations, and

D: Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+} and other divalent cations, (usually m<=n).

Zeolite structure also contains secondary building units (SBUs), which are formed by the linking of primary building tetrahedral (PBU). They consist of single and double rings of tetrahedra, forming the three dimensional structure of the zeolite material.

Secondary building units may be assembled in different ways to produce different types of frameworks (Figure 1.2). According to Gottardi (1978) the main secondary building units (SBUs) are:

a.- The 4 ring silicate, single or double (S4R and D4R),

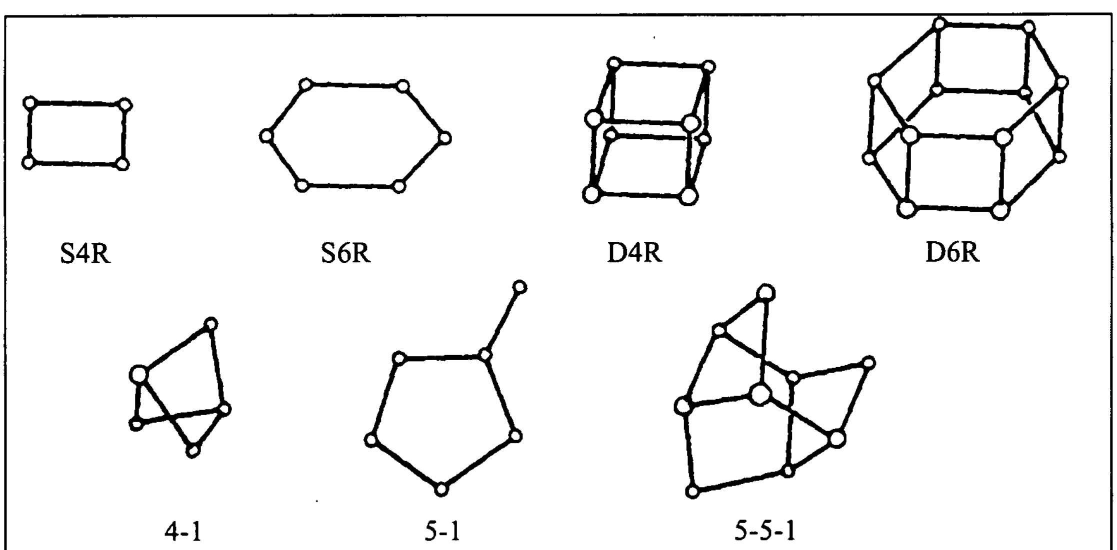
b.- The 6 ring silicate, single or double (S6R and D6R),

c.- The fibrous-zeolite unit (4-1),

d.- The Mordenite-unit (5-1),

e.- and the stilbite-unit (4-4-1).

Figure 1.2. The main secondary building units (SBUs) of zeolite. (after Gottardi, 1978)



1.3 Formation and Occurrence of zeolite minerals

The formation of sedimentary zeolites can occur by the reaction of volcanic glass (ash) or other alumino-silicate materials with pervading pore waters (ground-, lake-, or seawater). Zeolites are most readily found in alkaline environments (pH>8) because silica is more soluble under these conditions and thus the supply of most essential reactant is greater. Furthermore, because Ca, K, and Na are essential for zeolite structure formations; zeolites tend to form in an environment where these ions are abundant (Hawkins, 1984).

The formation of zeolites in nature is influenced by numerous factors, such as temperature, pressure, reaction time and the activities of dissolved species such as H^+, silica, alumina, alkaline and earth- alkaline ions.

Natural zeolite deposits are abundant world wide and available in mineable amounts. Their occurrences are mostly in sedimentary rocks and can be categorised into several types of geological environments including: saline – alkaline lakes; saline, alkaline soil systems, deep sea sediments; hydro-thermal alteration systems; hydro-thermal alteration deposits; and burial diagenetic or low-grade metamorphic rocks, (Hawkins,1984; Mumpton 1978).

1.4 Properties of natural zeolite

Zeolite mineral specie have unique properties which are dependent upon its various crystal structures and thus the type of inner cavities; pores; their size and form. Many of these properties are especially desirable for environmental protection, such as cation exchange capacity, ammonium capacity, acid stability, adsorption properties and wet attrition resistance.

1.4.1 Cation-Exchange Capacity (CEC)

Total CEC is one of the most important characteristics that gives zeolite species its importance in environmental protection at an industrial level. Cation exchange capacity is a measure of the number of counter ions present per unit weight or volume of the zeolite and represents the number of cations available for exchange (Semmens, 1984), in other words, it is a function of the degree of Al substitution for Si in the zeolite framework structure; the greater the substitution, the greater the deficiency of positive charge and the greater the number of alkali or earth alkaline cations are required for electrical neutrality, (Table 1.1), (Mumpton, 1984).

Factors which may reduce the exchange capacity;

1. The size of zeolite pores may be smaller than the ionic radius of some elements; which leads to cations being completely or partially excluded from exchange ; or when the ionic radius of the exchangeable cation is larger than the zeolites pore-volume and / or interconnecting channels and thus leads to ion sieving process (Semmens 1984).
2. Cations could be trapped in structural positions (sodalite units) and, therefore, will not be more exchangeable, (Mumpton, 1984).

Table 1.1 The relationship between Si/Al ratio and cation exchange capacity of some natural zeolites; after Colella (1996), * Data calculated from unit-cell formula; (after Mumpton (1984).

Zeolite	Structure Type cod	CEC* Meq/g	Si/Al ratio ranges
Chabazite	CHA.	3,84	1,43-4,18
Clinoptilolite	HEU.	2,16	2,92-5,04
Erionite	ERI.	3,12	3,05-3,99
Ferrierite	FER.	2,33	3,79-6,14
Heulandite	HEU.	2,91	2,85-4,31
Laumontite	LAU.	4,25	1,95-2,25
Mordenite	MOR.	2,29	4,19-5,79
Phillipsite	PHI.	3,31	1,45-2,87
Faujasite	FAU.	3,39	-

In general, the total cation exchange capacity depends on the type and volume of adsorption sites in zeolite; exchangeable cation sorts; ion radius and charge of cations in the solution, (Semmens and Seyfarth, (1978).

1.4.2 Adsorption Property

The inner structure of zeolite mineral which forms cavities and channels are generally filled with water molecules that form a hydration sphere around the exchangeable cations (such as Ca, Na, K and Mg) (Mumpton, 1984). Much of the water molecules can be removed from the cavities and channels after the zeolite minerals have been heated for several hours at different temperatures between 200 and 350°C; (zeolite dehydration or activation). This permits molecules with a fit diameter to enter the cavities and channels (e.g. water from

atmosphere humidity resulted in zeolite rehydration). Otherwise, a molecule with a large diameter would be excluded (Molecular sieving property). Thus, zeolite minerals have the ability to separate different gases on the basis of its size (Mumpton 1984). Also, polar gases are more preferable to be adsorbed than a non polar molecule (Flanigen 1984); for example CO_2 is more preferable than CH_4.

There are many factors which contribute to variations of zeolite adsorption properties, such as Si/Al ratio in the zeolite structure , pore volume and size, type of adsorption sites, size and shape of cages and channels in zeolite structure (Flanigen 1984). Natural zeolites (e.g. Clinoptilolite) have many commercial applications because of their adsorption and ion exchange characteristics, these include: purification of acid natural gas streams, drying and separation of air to produce oxygen and nitrogen (Flanigen 1984). Furthermore, the capability of zeolite to capture and immobilise ammonia in its structure makes it important in reducing odour intensities (Ronald Miner 1984).

1.4.3 Extensive Properties

Natural zeolite deposits are mainly soft, friable, and have a small attrition resistance; depending on its formation in the nature. For their economical uses, zeolite deposits should be rich in zeolite minerals of interest. In cases of use as cation exchange and adsorption materials, it should also have a high porosity in order to allow gases and liquids to be diffused between the grains, an acceptable packed bed density which is an important parameter by large scale applications, and the deposits should be soft enough to be crushed to their desired particle size (Mumpton, 1984). Other characteristics of zeolite deposits should also be determined, such as thermal stability and their resistance in acidic solutions.

1.5 Uses of Natural Zeolite

Based on their unique properties, including its low cost, world-wide distribution of zeolite deposits, more than 300.000 tons of zeolitic tuff is used yearly in the United States; Italy; Hungary; Bulgaria and in other countries of the world. Natural zeolites have been utilised in numerous areas of applications, such as ion exchangers in wastewater treatment (domestically-, industrial-, and agricultural origins); as lightweight aggregate in fertilisers and soil conditioners; in pozzolanic cements and concrete; as filler material in paper industry; as dietary supplements in animal husbandry; separation of nitrogen from air; as reforming petroleum catalysis; and other uses (Mumpton, 1978).

1.6 Jordanian Natural Zeolite

In Northeast Jordan in the Aritain area (120km NE Amman city- Appendix 1.1), Zeolite bearings tuff deposits were first discovered by Dwairi in 1984, who showed its presence (mainly containing Phillipsite mineral) in mineable quantities with traces of Chabazite and Faujasite, and suggested the economical utilisation of these Phillipsitic tuffs in industrial applications (Dwairi,1987, 1991). According to his study, zeolitic tuff deposits could be subdivided into three types depending on their degree of zeolitisation as follows:

a- Least zeolitized tuff (Violet zeolitic tuff).

b- Moderately zeolitic tuff (Brownish zeolitic tuff), and

c- Highly zeolitic tuff (Reddish zeolitic tuff).

Furthermore, the formation sequence of Jordanian Phillipsite, in the area of discovery, is explained as a reaction process of basaltic glass with alkaline water (Dwairi, 1987) in the following steps:

a- The reaction between volcanic glass and pore alkaline water leads to palagonite with a thin film of inter granular phillipsite.

b- Palagonite react with Mg-rich pore solutions leads to Mg-clay.

c- Mg-clay by alteration guides to alumino-silicate gel.

d- By the reaction of this gel with Na^+- and K^+- rich pore water, phillipsite mineral will be formed in-situ.

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Feb 1999
iii Foreword This edition of the U.S. Geological Survey (USGS) Minerals Yearbook discusses the performance of the worldwide minerals and materials industries during 1996 and provides background information to assist in interpreting that performance...
[http://discport2b.law.utah.edu/cdroms/MinMatInfo/Acrod...]
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☐ **15.** http://peaches/hochmuth/vegetar
Jan 2003
...R * * * * * * * Florida Postharvest **Horticulture** Industry Tour. Statewide. March 10...mail.ifas.ufl.edu Florida Postharvest **Horticulture** Institute at FACTS. (Florida Agricultural...mail.ifas.ufl.edu 116th Florida State **Horticultural** Society. Sheraton World Resort Hotel...
[http://www.hos.ufl.edu/vegetarian/03/February/Feb03.pd...]
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☐ **16.** Zeolites
Aug 2002
...erionite, ferrierite, heulandite, laumontite, mordenite, and **phillipsite**. More than 150 zeolites have been synthesized; the most common...deposits are chabazite, clinoptilolite, erionite, mordenite, and **phillipsite**. Other components, such as orthoclase and plagioclase feldspars...
[http://minerals.er.usgs.gov/minerals/pubs/commodity/ze...]
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☐ **17.** USGS Minerals Information: Zeolites
Robert Virta, Apr 2003
...erionite, ferrierite, heulandite, laumontite, mordenite, and **phillipsite**. More than 150 zeolites have been synthesized; the most...markets for natural zeolites are pet litter, animal feed, **horticultural** applications (soil conditioners and growth media), and wastewater...
[http://minerals.er.usgs.gov/minerals/pubs/commodity/ze...]
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☐ **18.** No Title
Nov 2002
Rocks for Crops - 279 Tanzania Total population (July 2000 estimate): 35,306,000 Area: 945,087 km2 Annual population growth rate (2000): 2.57% Life expectancy at birth (1998): 47.9 years People not expected to survive to age 40 (1998): 35.4% of total...
[http://www.uoguelph.ca/~geology/rocks_for_crops/52tanz...]
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L8: Entry 2 of 2 File: DWPI Nov 7, 2001

DERWENT-ACC-NO: 2002-131317
DERWENT-WEEK: 200218

TITLE: A functional tourmaline fertilizer for removing residual agricultural chemical from soil, activating water, improving acidic structure of ground, increasing soil fertility and promoting plant growth

INVENTOR: LI, X; YANG, W ; YANG, Z

PATENT-ASSIGNEE: LI X (LIXXI)

PRIORITY-DATA: 2001CN-0113963 (May 18, 2001)

PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE	PAGES	MAIN-IPC
CN 1320581 A	November 7, 2001		001	C05D009/00

APPLICATION-DATA:

PUB-NO	APPL-DATE	APPL-NO	DESCRIPTOR
CN 1320581A	May 18, 2001	2001CN-0113963	

INT-CL (IPC): C05 D 9/00; C05 D 11/00

ABSTRACTED-PUB-NO: CN 1320581A
BASIC-ABSTRACT:

NOVELTY - A functional tourmaline fertilizer for removing residual agricultural chemical from soil, activating water, improving acidic structure of ground, increasing soil fertility and promoting plant growth is prepared from tourmaline (10-50%), Chinese medical stone (25-60%), zeolite (10-50%), dolemite (5-10%), potash feldspar (5-10%), and calcite (5-10%) through crushing, mixing and firing.

ACTIVITY - Fertilizer.

No biological data given.

MECHANISM OF ACTION - None given.

ABSTRACTED-PUB-NO: CN 1320581A
EQUIVALENT-ABSTRACTS:

CHOSEN-DRAWING: Dwg.0/0

DERWENT-CLASS: C04
CPI-CODES: C04-A10; C05-A01A; C14-T;